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MEMORANDUM REPORT BRL-MR-3628

**NIGHT RECONNAISSANCE OPERATIONS
IN MISSION ORIENTED
PROTECTIVE POSTURE**

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Night Reconnaissance M60A3 MOPPIV Degraded Effectiveness		
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Military commanders are concerned about the impact chemical agents may have on operations. This is especially apparent in night reconnaissance operations which frequently require soldiers to wear mission oriented protective posture, level IV (MOPPIV); for the duration of the mission because of uncertainty about the location of chemical hazards. To evaluate this situation and provide a quantitative estimate of the degradation in performance, eight reconnaissance tasks were performed in a field environ-		

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ment, at moderate temperatures (52-84F). The tasks included: route reconnaissance, movement to two objectives, air and water sampling, hasty sketches of an objective, emplace a claymore mine and photography of a target. These operations were performed by several teams who alternated starts while wearing the standard battle dress uniform (BDU) and the MOPPIV ensemble. Individuals were highly motivated, in high physical readiness and psychologically prepared for the operation.

Data were analyzed using standard statistical procedures. A MOPPIV correction factor was defined as that value by which the time to complete a procedure in BDU should be multiplied to provide the time required to complete the task while wearing MOPPIV. These factors for the night reconnaissance tasks are:

Correction Factors for Wearing MOPPIV

Task	Factor	Probable Range
Route Reconnaissance	1.2	0.9-1.5
Move to First Objective	1.4	1.2-1.7
Take Air Sample	1.0*	0.6-1.2
Move to Second Objective	1.5	1.3-1.8
Take First Water Sample	1.1	0.3-1.8
Make Hasty Sketch of Dam	1.1	0.8-1.3
Take Second Water Sample	1.3	1.0-1.7
Move to Extract Point	1.5	1.0-1.9

*Probably not degraded

Although all the night reconnaissance tasks can be completed while wearing MOPPIV, there are certain considerations which need to be examined. First, loss of stealth and secrecy occur due in part to increased noise and lack of practice. Second, breathing is difficult while wearing the mask, considered to be due, in part, to overbreathing the mask during exertion, and water in the filter elements which resulted from increased perspiration. The suit becomes perspiration soaked with extensive work. What impact this has on suit value must be further evaluated. Water build-up of water in the mask and gloves was noticeable and a concern in extended operations as hands become sensitive and hyperhydrated. Overboots have inadequate traction and "road feel" resulting in a characteristic "shuffle walk" and frequent stumbling and falls. Teams wearing MOPPIV tend to move closer to roads than teams wearing BDU. Although a correction factor was not determined for photographing a target or for emplacement of a claymore mine, both tasks were completed while wearing MOPPIV with no apparent difficulty. The first-time-effect which can be explained as a lack of experience gained through repetition of tasks and the degradation due to lack of training are considered to be as important as the decrement due to the gear itself.

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I. INTRODUCTION

1. Background

Troop performance degradation due to chemical protective equipment has been of increasing concern to military commanders. This protective equipment is worn in one of four configurations referred to as Mission Oriented Protective Posture (MOPP) levels. MOPPIV in which all equipment is worn and sealed is the most protective, and the most bulky, cumbersome and restrictive mode. Personnel are protected at the expense of this encumbrance - a circumstance which results from impeded physiological functions which include vision, hearing, speaking, manual dexterity, and others. This encumbrance produces degradation in the form of (usually) increased time to complete tasks and in some cases reduced accuracy. For the purposes of this study, accuracy was maintained and time to complete a task was the measure of the extent of personnel degradation due to wearing MOPPIV. To quantify this degradation for use in simulations, operations research and other studies of unit effectiveness and combat readiness, field studies are necessary since laboratory exercises typically introduce artifacts that can bias results.

To satisfy this need, an evaluation was performed in response to a requirement submitted to an extensive DoD sponsored and Dugway Proving Ground (DPG) administered Chemical Biological Joint Contact Point and Test Program, referred to as Project DO-49, to quantify the effect that wearing MOPPIV has on personnel performing military tasks. The current program includes five specific operational areas (Table 1) with additional emphases on operations during cold, moderate and hot temperatures.

TABLE 1. Performance Oriented MOPPIV Evaluations

Operational Areas
Armor Operations
Maintenance Operations
Missile Operations
Night Recon Operations
Signal Operations

The Vulnerability/Lethality Division of the Ballistic Research Laboratory (BRL) has an extensive ongoing program for assessing the vulnerability of military systems on the integrated battlefield to include the effects of conventional, nuclear, and

chemical munitions on the effectiveness of various units. The model for this program is the Army Unit Resiliency Analysis (AURA) methodology.¹ AURA utilizes inputs from all areas which impact on the ability of a unit to accomplish a mission including the effect of wearing MOPPIV. Since degradation data is not available in many areas and because of the need to include degradation performance in unit effectiveness studies using AURA, the BRL is developing techniques² to estimate personnel degradation due to MOPPIV. In this report, "MOPPIV" refers to wearing of the equipment at level IV, and "MOPPIV Time" to the amount of time required to complete a task while wearing level IV.

One major concern in interpreting field data is the need to establish a degradation value. It is not unusual to find judgments made on the effect of protective equipment with no real measurement of the effect or the variation experienced. One purpose of this effort is to provide a numerical estimate of the equipment effect and the associated variation.

This report presents the results of Night Reconnaissance Operations conducted at Camp Pendleton, CA in September 1985 under moderate to warm temperatures (52-84°F; 11-29°C). A daily summary of temperature and relative humidity is included in Appendix A. Trials were performed by members of Company C of the 1st Reconnaissance Battalion, 1st Marine Division, Fleet Marine Force. All trials were held during the hours of darkness with teams remaining in MOPPIV without relief for the entire trial period of approximately eight hours.

2. Objective

The primary objective of this program was to evaluate the operational capabilities and to quantify the degradation for personnel dressed in complete MOPPIV performing a night reconnaissance mission.

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1. J.T.Klopacic, and L. K. Roach, "An Introduction to the Use of the Army Unit Resiliency Analysis (AURA) Methodology: Volume I," US Army Ballistic Research Laboratory, Memorandum Report No. 3384, September 1984.
 2. David W. Harris, "A Degradation Analysis Methodology for Maintenance," Master of Science Thesis, Georgia Institute of Technology, April 1985; Sponsor: C. Wick, BRL.

II. APPROACH

1. Overview

The measure of degradation for each performed task was the time difference between performing the task in Battle Dress Uniform (BDU) and MOPPIV. For these trials there were three teams consisting of four members each. Degradation measurements were made for team tasks, such as movements to objectives, as well as individual tasks, such as taking a photograph. Accompanying each team was a trained observer whose goals were to time each individual task and rate the overall operation. The tasks were measured in real time and recorded on a data sheet carried by the observer.

Individuals were trained in the appropriate military operational speciality (MOS) and were highly motivated. Each had experience working together as a team. The teams, however, did not have prior practice before completing the first trial of this exercise. Teams were familiar with chemical protective equipment, but received no special prior instruction in the wearing or completing the assigned tasks in MOPPIV.

Since these tests were repetitive, individuals gained experience as they progressed through the trials. In an effort to control and later estimate the experience effect, a record was noted on the order of start; i.e., whether a team was in BDU or MOPPIV the first time it performed a trial. For the purposes of this analysis, all references to "first time effect" pertain to the first performance by each team.

For each trial, three items of data were recorded: first, the time to complete a task; second, the protective profile (BDU/MOPP); and third, whether it was the first trial or a subsequent one.

A multiple linear regression technique explained in Appendix B, was used to estimate the effect of the chemical protective equipment and the effect of practice on the time to complete the various tasks. As part of the analysis it was evident that tasks containing cross country movement could not be analyzed without first considering the methods and techniques of movement.

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3. C.H. Wick, J.T. Klopac, "Maintenance Operations in Mission Oriented Protective Posture Level IV (MOPPIV)." Draft DPG Report 1985.

2. Trial Description

The trials were designed to collect performance data from a night reconnaissance team performing a night reconnaissance patrol with a mission to collect intelligence information and avoid enemy contact. The exercise was conducted during the hours of darkness and included a route reconnaissance, target photography, movement to two objectives and the extraction point, emplacement of claymore mines, collection of air samples, collection of water samples, and the development of a hasty sketch of a dam. At the first objective, claymore mines were emplaced, photographs were made of a target, and an air sample was taken using the M256 kit. After moving to the second objective, an initial water sample was taken and a hasty sketch of a dam was made. Before reaching the extraction point the team stopped and took a second water sample. The tasks are presented in Table 2 and were completed in the listed order.

TABLE 2. Night Reconnaissance Operations

Task
Route Reconnaissance
Photograph a Target
Move to First Objective
Emplace Claymore Mine
Take Air Sample
Move to Second Objective
Take First Water Sample
Make Hasty Sketch of Dam
Take Second Water Sample
Move to Extraction Point

a. Movement Tasks. Four tasks required the teams to traverse from one identified point on the course to another. The first was travel during the route reconnaissance of a road, the second was travel from a choke point to an observation point, the third was travel from observation point to a second observation point, and finally, the fourth was travel to the extraction point. In addition to the time to complete these tasks, comments on the ability of a team to maintain patrolling disciplines such as stealth, listening, and silent communication were collected. The time to complete a passage from one point to another was

measured from the departure of the first person to the arrival of the last.

b. **Other Tasks.** The remaining events are considered stationary tasks and, as such, were measured from the beginning of the activity to the conclusion. The collection of the two water samples required a short travel distance by one team member and was considered a part of the collection procedure. Air sample collection using the M256 kit, the photograph, and the hasty sketch were from sites occupied by the team.

3. Trial Matrix and Questionnaire

a. **Trial Matrix.** The order of start was recorded to assist in determining the effect of training on performing the various tasks. The trial matrix indicating the day, the team, and the uniform worn is given in Table 3. On the first night of operations two teams completed the course; team one in SDUs and team two, in MOPPIV. The team wearing MOPPIV started 30 minutes after the team wearing the BDUs because of darkness restrictions. It was determined that one team per night was appropriate for the course and the matrix reflects this condition for the following days.

TABLE 3. Trial Matrix

Day	Team	Uniform
1	1	Utility
1	2	MOPPIV
2	3	MOPPIV
3	1	MOPPIV
4	3	MOPPIV
5	2	Utility
6	1	MOPPIV
7	2	MOPPIV
8	3	Utility

b. **Survey.** At the conclusion of a MOPPIV trial, individuals were asked to complete a questionnaire. Each was asked to rate the perceived difficulties encountered while wearing the mask, boot, and overgarment. The items rated are given in Table 4. Ratings were determined by checking one of four boxes: none, minor, average, and major. Each box later received a numerical weight of 0, 5, 10 and 15, respectively, for further analysis.

TABLE 4. Participant Questionnaire

Number	Situation
1	Mask-Vision Hampered
2	Mask-Perspiration Buildup
3	Mask-Breathing Difficulties
4	Mask-Voice Communication
5	Boots-Movement Difficulties
6	Boots-Slipping
7	Gloves-Operating Equipment
8	Gloves-Performing Tasks
9	Overgarment-Bulkiness
10	Overgarment-Heat Buildup

III. RESULTS/DISCUSSION

In reporting the data obtained from the trials three distinctions are made. The first is BDU, the second is MOPPIV which refers to the first trial in which a team wears chemical protective gear, and the third is MOPPIV-2 which is the second time a team wears chemical protective equipment. Team numbers ending in "B," "M," and "2" reflect this distinction respectively. Teams performing a trial for the first time are identified with an "*."

1. Results

Field data is presented in the following tables expressed as the time to complete a task in minutes for each team.

TABLE 4. Field Data

Team	Time in Minutes				
	Task				
	Route Recon	Photograph Target	Move to First Obj	Emplace Claymore	Air Sample
1-B*	181	5	112	a	18
1-M	136	3	85	13	17
1-M2	141	5	121	12	15
2-B	67	7	94	8	16
2-M*	99	17	111	9	23
2-M2	55	4	100	6	13
3-B	41	5	36	4	21
3-M*	107	4	152	5	4
3-M2	102	1	106	5	20
* Uniform for first performance					
a = no data					

TABLE 5. Field Data (continued)

Team	Time in Minutes				
	Task				
	Move to 2nd Obj	Take first Water Sample	Hasty Sketch	Take second Water Sample	Move to Extraction
1-B*	89	32	32	51	51
1-M	92	31	31	50	50
1-M2	88	20	20	56	49
2-B	60	20	20	51	41
2-M*	63b	15	15	23	39
2-M2	83b	5	15	42	43
3-B	20	11	11	19	32
3-M*	91	35	35	108	109
3-M2	78	22	22	66	45
* Uniform for first performance					
b = inferred					

2. Discussion

In two events, indicated by an "a" in Table 5, data are not reported due to either equipment malfunctioning or the time being incorrectly noted. Since the data represented the first-time experience for one team in BDTs, these losses resulted in insufficient data to complete a regression analysis for either photographing a target or emplacing a claymore. In two further instances, indicated by a "b" in Table 5, values were inferred by cross reference with other data and as such represent a upper

bound for completing the event.

During these trials no participant "dropped out" because of the temperature or other conditions of the exercise. The following observations were reported during the exercise. During one trial a team attempted to take a "short-cut" across a small hill - a decision which resulted in a slightly longer completion time. The evaluator attributed this attempt to the result of heat build up and fatigue as the team had just finished climbing a road with a steep incline used for the route reconnaissance and were hot and tired. Several participants reported headaches as the result of prolonged mask pressure on the temples and others indicated that rubbing of the mask on the face produced tenderness. The extended exercise in the warm temperatures produced sweat in the gloves which made the hands slippery and tender. Individuals, with only momentary exceptions, remained in MOPPIV for the entire trial period.

IV. ANALYSIS/DISCUSSION

A regression analysis was used to analyze the Fight Reconnaissance data. This technique is explained in Appendix B and an example provided in Appendix C. A regression analysis for each task performed during the night reconnaissance mission is presented. In addition, the questionnaire responses are presented and discussed.

1. Analysis

Tasks were analyzed using the regression technique. The results of these analyses are given in Table 6, where T' is the practiced, unencumbered term, a' is the clothing correction, and b' is the training correction. The MOPPIV degradation factor for any particular task is defined as $T'/(T' + a')$. The MOPPIV correction factor is the inverse of this term and is used to multiply the time to complete a task while wearing BSUs to give an estimate of the time to complete the task while wearing MOPPIV. A negative a' or b' indicates that a task was completed in less time by a team wearing MOPPIV or by an unpracticed team respectively. Generally, such results are attributed to non-correctable inconsistencies in some team's performance for that task.

2. Discussion

The maximum effect of wearing MOPPIV is seen during movement. Other tasks appear to be less affected. However, those tasks were not physically demanding. Evidently, as the team wearing MOPPIV progressed in the mission, fatigue began to influence the MOPPIV degradation factor. Stationary tasks, however, were completed with little degradation attributable to the differences in clothing. Few comments were collected in these tasks. In all

TABLE 6. Regression results

Task	Nondimensionalized Coefficients			MOPPIV Factor
	Unencumbered Term T_0'	Clothing Correction a'	Training Correction b'	
Route Reconnaissance	0.81	0.16 ± 0.22	0.44 ± 0.23	1.19 0.93-1.47
Move to First Objective	0.64	0.27 ± 0.15	0.27 ± 0.15	1.43 1.19-1.67
Take Air Sample	1.16	-0.14 ± 0.32	-0.01 ± 0.32	0.88 0.60-1.16
Move to Second Objective	0.61	0.33 ± 0.17	0.14 ± 0.17	1.50 1.27-1.81
Take First Water Sample	1.84	-0.51 ± 0.85	0.55 ± 0.05	0.95 0.26-1.18
Make Hasty Sketch of Dam	1.03	0.05 ± 0.27	0.33 ± 0.27	1.05 0.79-1.31
Take Second Water Sample	0.73	0.25 ± 0.26	0.24 ± 0.26	1.34 0.99-1.70
Move to Extract Point	0.73	0.33 ± 0.32	0.51 ± 0.32	1.45 1.01-1.89

cases of teams wearing MOPPIV, most members thought that they could have performed better with practice and training.

a. **Movement Tasks.** Tasks which required the team to move cross country were completed while wearing MOPPIV with correction factors ranging from 1.2 to 1.5. On the surface, this would seem to indicate that time for completion of these tasks is only a minor concern while wearing MOPPIV. However, stealth is generally lost during night movement while wearing MOPPIV because of increased noise, loss of vision, difficulty in communication, and general lack of secrecy when moving from one area to another. Factors such as these cause certain missions to be judged too risky. However, it should be noted that if the team is wearing MOPPIV, it would be likely that the enemy would likewise be wearing chemical protection and possess many of these same degradations. The two major observations are increased noise and the appearance of being more detectable.

Depending upon work requirements, teams wearing MOPPIV breathe harder, talk louder, and generally walk with a shuffle. Breathing noise was one of the loudest sounds during road movement, particularly after physically demanding tasks, such as the route reconnaissance involving a steep incline. Reducing the level of exercise, perhaps by taking longer to traverse the road,

should reduce the breathing rate and the associated noise.

While attempting to talk in low voices, teams experienced difficulty being understood and were nearly shouting - or considered themselves to be shouting - in order to be understood. This led the individuals to perceive themselves to be loud, when in fact their voices were muffled by their masks and did not seem to travel over distance. The individuals may have shouted but the sound was attenuated. However, as a result of their perceived loss of stealth other actions may not have been as guarded as when wearing BDUs. This factor would tend to reduce the time increases that would otherwise be attributed to MOPPIV degradation.

Another effect of reduced auditory ability was noticed. During routine movements, individuals could not hear the man following, this resulted in frequent turning to observe and confirm his location. As a result, the team wearing MOPPIV tended to be closer together during patrol.

Traction was poor with the boots which, depending upon the surface, resulted in slipping. To counter this poor "road feel" a "shuffle walk" often developed to keep contact with the ground and to push objects out of the walk path. Limited vision restricted the "look down" ability which resulted in frequent snags and stumbling into obstacles on the ground. This frequently contributed to stumbling and several members fell while on patrol. One man lost a boot during a cross country movement task and was unaware that it had come off due to the general loss of perception. The laces on the boots tended to become untied even after simple road movement tasks.

The overgarment provided enough insulation to cause team members to heat up during periods of hard work and then become cold, as the result of being wet, when vigorous activity stopped. Overgarments became saturated with perspiration as the result of the work required during the exercise. (What this saturation does to protection from chemical agents must be determined.) The water buildup in the mask and gloves was noticeable. The hands became sensitive and hyperhydrated as a result of wearing the gloves during this exercise. The cotton liner was saturated, but apparently continued to provide some abrasion protection.

Manipulation of communication gear was difficult while wearing MOPPIV as a result of reduced manual dexterity and near vision. Operators had difficulty reading the code sheets or even finding the code sheets. In fact, while one hand was sufficient to locate code sheets when wearing BDUs, two hands were needed to find these items in pockets when wearing MOPPIV due mainly to the loss of tactility.

The above interactions resulted in teams wearing MOPPIV moving closer to the roads than teams wearing BDUs. The teams

wearing MOPPIV were able to complete their mission but did so in a noisier manner than when wearing BDUs, resulting in easier detection. Listening equipment could be used to reveal the team's location and even the fact that the team was wearing MOPPIV. The noise would result because hard breathing in the protective mask and the rattle of the boots are distinctive sounds.

b. Stationary Tasks. Few comments were registered or difficulties observed for the stationary tasks: photographing the target, emplacing a claymore mine, making a hasty sketch, and taking a water sample. Although these tasks were influenced by the wearing of MOPPIV all tasks were completed. It was observed that practice is required to utilize the camera while wearing the protective mask. The photographs obtained with the present system were completely adequate for the mission requirements. On the other hand, teams were able to emplace a claymore mine with no apparent difficulty while wearing MOPPIV.

c. Survey Questions. Responses from each individual were weighted by giving a numerical value to the response terms accordingly: none = 0, minor = 5, average = 10, and major = 15. The average was then determined to estimate the level of perceived difficulty due to each factor. Results indicate (Table 7) that heat buildup in the overgarment and perspiration buildup in the mask were primary concerns.

It is interesting to note that using equipment and performing tasks while wearing the protective gloves and the bulkiness of the overgarment were ranked as the lowest difficulties. It is possible that this is because tasks typically completed by a reconnaissance team do not require high levels of manual dexterity or hand-to-eye coordination. Important tasks tend to include large body movement, far vision, and other similar skills. Further, the energy expended while patrolling is generally considered to be greater than in stationary tasks. Thus, it was not surprising that the results of the survey results indicate heat and perspiration buildup to be problems with other factors less important.

TABLE 7. Survey Results

First and Second Wearing of MOPPIV							
Factor	Team						Average
	1 1st	1 2nd	2 1st	2 2nd	3 1st	3 2nd	
Mask/ Vision	8	8	15	10	5	5	9
Mask/ Water Build-up	9	13	14	15	9	11	12
Mask/ Breathing	9	11	6	14	8	9	10
Mask/ COMMO	4	5	13	8	11	9	8
Boots/ Movement	3	9	11	10	13	13	9
Boots/ Slipping	4	9	5	10	15	13	9
Gloves/ Operating Equipment	4	6	9	10	6	6	7
Gloves/ Tasks	4	6	10	9	6	6	7
Overgarment/ Bulkiness	4	3	4	8	8	8	7
Overgarment/ Heat Bld-up	10	15	13	15	11	11	13
Average	5.3	9.2	10.0	10.9	9.2	8.8	

V. SUMMARY/CONCLUSIONS

The quantification of the degradation of personnel performing in MOPPIV was determined for each night reconnaissance task. The inverse of the degradation is the MOPPIV correction factor which is presented in Table 8. The multiplication of the time required to perform a task while wearing BDU (referred to as the BDU value) by this factor produces an estimate of the time required to complete the task while wearing MOPPIV.

TABLE 8. MOPPIV Correction Factors

Task	Factor	Probable Range
Route Reconnaissance	1.2	0.9-1.5
Move to First Objective	1.4	1.2-1.7
Take Air Sample	1.0*	0.6-1.2
Move to Second Objective	1.5	1.3-1.8
Take First Water Sample	1.1	0.3-1.8
Make Hasty Sketch of Dam	1.1	0.8-1.3
Take Second Water Sample	1.3	1.0-1.7
Move to Extract Point	1.5	1.0-1.9
*Probably not degraded		

These field measurements of MOPPIV operations have provided some valuable data for the evaluation of troop performance. The performance information which resulted has improved estimates for completing similar tasks in MOPPIV and improved operations research estimates of unit effectiveness and unit readiness.

Other conclusions and observations based on the results of this study are:

- Although night reconnaissance movement tasks can be completed while wearing MOPPIV, loss of stealth and secrecy occurs largely due to increased noise and lack of practice.
- Breathing difficulties while wearing the M17A1 Mask and heat buildup from wearing MOPPIV are important concerns.
- The first-time-effect (lack of experience gained through repetition of tasks) and degradation due to lack of training are as significant as the MOPPIV degradation.
- The overgarment becomes perspiration-soaked with extensive work. Effects of this condition on the protective value of the overgarment must be determined.

- Buildup of water in the mask and gloves was noticeable and a concern. Hands became sensitive and hyperhydrated after wearing the gloves.
- Protective overboots have inadequate traction and "road feel" resulting in a characteristic "shuffle walk" and frequently results in stumbling and falls.
- Teams wearing MOPPIV move closer to roads than teams wearing BDU.
- Although a MOPPIV correction factor was not determined for photographing a target or for emplacing a claymore mine, both tasks were completed while wearing MOPPIV with no apparent difficulty.

All tasks were completed while wearing MOPPIV. It should be noted, however, that the overall tactical situation is important in considering the success of this operation. If the enemy threat is low or minimal the mission could be expected to be completed with a little more time allocated. If the enemy threat is high, including listening devices and other counter-measures, then the mission could be at risk because the team may be detected and neutralized.

Finally, it should be noted that the limited sample size available for this evaluation made the data analysis particularly sensitive to inconsistencies in performance of any task by any team. Data currently being evaluated in follow-on night reconnaissance evaluations should allow determination of MOPPIV correction factors with tighter error bounds.

APPENDIX A

Climatic Conditions

Daily Temperature and Relative Humidity Record

During the exercise the temperature and relative humidity as well as the general atmospheric condition was recorded at 30 minute intervals. Typically the temperature reduced during the night as did the relative humidity. The presence of ground fog from the ocean, however, on days 1 and 6 maintained the high humidity. The exercise was conducted at Camp Pendleton with historically high temperatures and low relative humidity. The high, low, and average temperature and relative humidity are given in Table A-1.

TABLE A-1. Temperature and Relative Humidity

Day	Degrees Celsius			% Relative Humidity		
	High	Low	Average	High	Low	Average
1	18.2	13.8	15.3	64.0	39.4	54.4
2	16.4	11.3	13.3	38.4	17.7	23.9
3	18.2	16.3	17.1	30.5	8.2	15.3
4	20.2	17.7	19.3	21.4	10.2	15.2
5	28.2	26.6	27.7	25.9	13.9	17.4
6	24.9	22.7	23.3	50.9	43.9	46.1
7	25.9	23.3	24.5	50.6	30.3	39.3
8	28.6	27.9	28.3	25.6	20.6	23.0
Average	22.6	19.9	21.1	38.4	23.0	29.3

APPENDIX B

Regression Analysis Methodology

Regression Analysis Methodology

In any attempt to measure the dependence of some entity upon a particular factor, it is essential to control, or at least account for, other factors which can influence the entity. Unfortunately, the isolation and elimination of unwanted factors is often not possible being particularly true in the case of experiments involving human performance and response. In such experiments, the use of human subjects introduces a myriad of personal factors, many of which are as subtle as they are unquantifiable. The experiments to measure the degradation of soldier performance due to the wearing of chemical protective (MOPP) gear certainly fall into this category.

One approach to reducing the effect of unwanted factors is to disregard any data which involves unwanted factors. Thus, for example, the unwanted factor of "no-practice" which might cause performance in first iteration trials to be worse than in those that follow, is often controlled by conducting a sufficient number of "dry-runs" to assure that no data trial is unpracticed. Unfortunately, in the case of the MOPP degradation experiments, limitations in troop and staff availability make dry-runs an unaffordable luxury and all trials had to be used for data generation purposes.

Our solution to this problem has been to account for the effect of practice by including an experimentally determined, linear correction term for first trials. Since it was also assumed that the effect of wearing MOPP gear could be expressed as a linear correction term, we were able to use standard multiple linear regression techniques to reduce the data and extract MOPP correction factors. The basic linear equation used to account for the time of any given trial of a particular soldier activity is:

$$T = T_0 + a(x) + b(y) \quad (B-1)$$

That is, the expected time T is the sum of the intrinsic time T_0 required for the task, a correction term (a) for wearing MOPP gear and a correction term (b) for an unpracticed trial. This technique has been used for the reduction of data from all the MOPP degradation tests listed in the introduction of this report. Equation B-1 is further examined in appendix C.

In the current test another uncontrollable factor was introduced. The nature of a night reconnaissance mission requires that the members of the patrol move stealthily; sacrificing speed in favor of stealth. Unfortunately, this results in a subjective decision on the part of each patrol as to the speed that it should take. This in turn results in an undesirable biasing of the regression results, since the large times recorded by the slower, more cautious patrols dominate the regression analysis.

Since each patrol conducted three trials (two in MOPPIV and one in BDU), it was decided to attempt removal of the bias by normalizing the results for each patrol to its own baseline. The choice of the baseline was guided by the following considerations: At least one of the patrols conducted its first (unpracticed) trial in BDUs while the others began in MOPPIV. Thus, normalization of a patrol's results to its first trial or to its BDU trial would have introduced additional errors. However, because each patrol conducted two MOPPIV trials, every unit had at least one practiced MOPPIV trial. Assuming that the only variants in the study are (1) MOPP - no MOPP, (2) practice - no practice and (3) intrinsic team stealth, the difference between the times for each team's practiced MOPPIV trials should be due only to the intrinsic team stealth. Normalizing each team's times to its practiced MOPPIV trial time results in ratios of times in which each team's intrinsic stealth factor has been "canceled out".

If we let (') indicate that the above normalization has taken place, the regression equation for the normalized time, T' , becomes:

$$T' = T'_0 + a'(x) + b'(y) \quad (B-2)$$

Clearly, a' can no longer be interpreted as the additional time required for a task due to the wearing of MOPPIV. However, the ratio:

$$CF = (T'_0 + a'(x)) / T'_0 \quad (B-3)$$

is proportional to the increased time due to the wearing of MOPPIV; i.e., CF is an appropriate correction factor to be applied to the no-MOPP time for any particular patrol to estimate the time that would be needed by that team to do the same task while wearing MOPPIV.

The question arises as to whether a similar normalization may have been justified for the performance of particular individuals or teams in the other units studied in this series of MOPPIV evaluations. For example, in reducing the data on the disassembly and reassembly of a gearbox from the M-901, should the times of each of the several test subjects have been normalized to some common, subject-related datum?

We believe that the answer is "No." The reason is that tasks like the assembly/disassembly are well defined: each individual went through the same sequence of steps, removed the same snap rings in the same order, etc. Therefore, the actual times are meaningful numbers. For example, the unencumbered, practiced time for disassembly/reassembly is the time that would appear in the published time standard for that task. (In fact, validity of the data required that the times measured in our trials were consistent with the standard, actual times.) On the other hand, it

is not meaningful to ask how long it takes to maneuver stealthily from point a to point b. The answer is dominated by random variables such as the number of stops made, time spent listening, detours taken, etc. It must be concluded that the night reconnaissance trials warrant a different data reduction technique than that used for more vigorously defined tasks.

APPENDIX C

Regression Analysis Example

Multiple Linear Regression

Regression analyses are used to quantify the relationship between variables where the value of one is effected by changes in others. The type of uniform worn and whether or not the event was completed for the first time, either in BDU or MOPPIV, are independent variables. A multiple linear regression allows a dependent variable to be estimated by quantifying the relationship to several independent variables. In this instance, time to complete a task is the effected or dependent variable. Interactions and variables not measured are reflected in the error term and include such effects as team work and leadership. An estimate of how well the regression estimates the dependent variable is expressed by the multiple correlation coefficient. Analysis then can be used to determine the effect of MOPPIV and the first time effect on the total time to complete a task.

For Troop Performance studies the regression expression is represented by:

$$T = T_0 + a(x) + b(y) + e \quad (C-1)$$

Where "T" (the dependent variable) is the total time in minutes to complete a task, " T_0 " (the intercept) is the practiced, unencumbered time, "x" (first independent variable) is the clothing type, "y" (second independent variable) is the order in which an event was started and "e" is the error term. "x" is the BDU or MOPP condition and is represented by either a "0" or a "1", since it is assumed that the clothing contribution would be zero for BDU. Likewise, if a team was working an event for the first time "y" would be assigned a "1" and if the team has completed the event before a "0" would be assigned since no first time effect would be present. The expression, without the error term, then becomes:

$$T = T_0 + a + b \quad (C-2)$$

Where "a" and "b" represent the correction in minutes for MOPPIV and practiced factors, respectively. Therefore, a team completing an event for the first time in BDU is expressed as:

$$T = T_0 + b \quad (C-3)$$

A team completing an event in BDU for the second or greater time would simply be " T_0 ", ($T = T_0$). By wearing MOPPIV this team would add a MOPPIV time and be expressed as:

$$T = T_0 + a \quad (C-4)$$

The event time for the same team completing the event for the first time and wearing MOPPIV would be expressed as:

$$T = T_o + a + b$$

(C-5)

Example of Regression Analysis:

An example case will be replacing the shroud during the removing/replacing of the M60A3 transmission, accomplished during the moderate temperature Maintenance Evaluation. All other tasks and events were likewise evaluated and are included in the results.

Replacing the shroud includes the placement of the shroud on the powerpack and the connection of the attachment bolts. The data for evaluation is given in Table C-1, where team 1 replaced the shroud twice with the first occurrence in BDU in 7.8 minutes and the second occurrence in MOPPIV in 14.2 minutes. For this example, the resulting regression coefficients in Table C-2, are " T_o ", the practiced, unencumbered time, "a", the additional time for MOPPIV, plus or minus the standard deviation and "b", the additional time needed if the event is done for the first time, plus or minus the standard deviation. Thus, the expected time for replacing the shroud is 5.8 minutes for a practiced unencumbered team. An additional 3.8 minutes is added to the total if the team was wearing MOPPIV, for an expected time of 9.6 minutes. This additional MOPPIV time could be as much as 11.5 minutes ($9.6+1.9$) or as little as 7.7 minutes ($9.6-1.9$). No additional time is needed to complete this replacement for the first time because, in this example the coefficient is negative. In other events this first time correction is calculated the same as for the MOPPIV effect to determine the additional time needed.

TABLE C-1. Data Used in Example Regression

Team	BDU	MOPPIV	1st Time
1	7.8	14.2	BDU
2	4.6	24.6*	MOPP
3	5.8	10.2	BDU
4	6.4	7.4	MOPP
5	3.6	6.3	BDU

* Data excluded due to the incorrect removal of items which required extra time to replace.

TABLE C-2. Example Regression Results

Coefficients
$T_o = 5.8$
$a = 3.8 \pm 1.9$
$b = -0.5 \pm 2.0$

In addition, the quotient resulting from " $T_o / (T_o + a)$ " represents the degradation for wearing MOPPIV. That is, the unencumbered practiced time " T_o " divided by the total time for MOPPIV " $T_o + a$ ". Thus a team replacing the shroud in MOPPIV is degraded to 60 percent of their practiced, unencumbered ability, $5.3 / (5.8 + 3.8) = 0.60$. In a similar calculation, the degradation for doing the job for the first time results from the quotient of " $T_o / (T_o + b)$ ". In this example no degradation was determined for doing the event for the first time. A team is degraded to 0.63 if replacing the shroud for the first time and in MOPPIV, where both MOPPIV and first time coefficients are added in the denominator, ie. " $T_o / T_o + a + b$ ". The quantity " $(T_o + a) / T_o$ " (which is the inverse of the degradation factor) is called the MOPPIV Correction Factor. This factor when multiplied by " T_o " gives the expected time to complete a task in MOPPIV. For this example the correction factor is 1.66. The estimated time for this event is then 5.8×1.66 or 9.6 minutes. The results give a real number estimate of the effect of MOPPIV on this job performance (Table C-3).

TABLE C-3. Example Regression Estimates

Calculations
$T_o = 5.8$
$T_o + a = 9.6$
$T_o + b = 5.3$
$T_o + a + b = 9.1$
$T_o / (T_o + a) = 0.60$
$(T_o + a) / T_o = 1.66$
$T_o / (T_o + b) = 1.09$
$a / T_o = 0.66$

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